DEEP SEA MOLLUSKS AND THE CONDITIONS UNDER WHICH THEY EXIST.*

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I propose on the present occasion to lay before you a statement of the conditions which characterize the life of Mollusks in the Deep Sea, so far as they are known to us, and to discuss briefly the effect of these conditions upon the animals subjected to them; the contrast which their life presents to that of shallow-water mollusks ; the peculiarities preserved or the modifications induced by the special environment ; together with some notes on interesting or remarkable forms discovered in deep water.

Once for all, it must be understood that exploration of the deep sea fauna has only begun ; that the area swept by the trawl and dredge compared with that which remains unknown, is almost infinitesimal ; and, of the material secured by dredging, a large portion is fragmentary and imperfect. In short what we know about the deep-sea mollusks can only be regarded as a foretaste of that knowledge which future years may be expected to supply.

In an address of this sort bibliographical references would be out of place. I will only say that the literature of the subject is almost wholly confined to the publications of the last twenty years, and consists in large part of the reports by various spec-

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ialists on such voyages as those of the British vessels, *Lightning*, *Porcupine*, *Valorous* and *Challenger;* the French *Talisman*, and *Travilléur;* the Norwegian, North Atlantic Expedition; and the explorations of our own Coast Survey, Fish Commission, and Navy on the *Blake*, the *Fish Hawk*, the *Albatross*, and other well known vessels. The most distinguished naturalists of this country and of Europe have added to their reputation by the investigation of the wonderful fauna revealed by these explorations. The most extensive and important single series of Scientific Reports ever published as the result of a single expedition are those which bear the name of the Challenger upon their capacious covers. Next to these come the Reports of the United States Fish Commission, under the leadership of Prof. Baird, and then follows a host of minor documents which it is impossible to enumerate at the present time.

What I have to present to you this evening is rather a discussion of conditions and principles than an exhibit of particular facts or observations.

In order that their existence may be maintained the abyssal mollusks require oxygen to ærate their circulation, food to eat, and a foothold upon which they may establish themselves. It is necessary that the conditions should be such as will not prevent the development of the eggs by which successive generations are propagated, and that they do permit it may be assumed from the very fact that mollusks in large numbers have been shown beyond all question to exist on the oceanic floor wherever this has been explored.

Formerly when dredging with the usual appliances in small boats, one hundred fathoms (six hundred feet) was considered extremely deep. If one stands at the foot of the great Washington obelisk and looks up, the idea of collecting a satisfactory representation of the insects and plants on the ground at its base by dragging a six foot trawl or dredge by a line let down from the apex of the monument, strikes one as preposterous. Yet the monument is less than one hundred fathoms high. Multiply this height ten or fifteen times and the idea seems, if possible, still more unreasonable, yet it is a fact that successful dredging has been done from a height above the sea-bottom of not less than twenty-five times the height of the Washington monument. Living animals have been secured from a depth equalling the distance from the Capitol to Rock Creek, or from the Washington monument to the mansion at Arlington, that is to say about two and a half miles.

It is therefore evident that in speaking of dredging, we must revise our terms and define them so as to conform more nearly to the new conditions under which such work is done.

The waters immediately adjacent to the shores were long ago divided by Forbes and other pioneers in marine exploration into zones or areas according to the conditions characterizing them ; as, for instance, the Laminarian zone or region of brown kelp, the Coralline zone or region of stony algæ, &c. But for general purposes and to contrast the areas of the whole sea, one with another according to their chief characteristics, we may now divide the entire sea bottom into three regions.

The first is that to which light can penetrate and therefore where marine vegetation can exist. This is the Litoral region and in a general way, modified by especial conditions at particular places, it may be regarded as extending from the actual shore out to the limit of one hundred fathoms. Beyond this it is practically certain that no light reaches the bottom of the sea and no sea weeds grow. Outside of this the borders of the continents slope gradually to the bottom of the ocean, which is found usually at a depth of about 2,500 fathoms.

On the upper parts of these continental slopes the conditions are often very favorable for marine life. Currents of comparatively warm water, like the Gulf Stream, sweep along bringing fresh pure water and supplies of food to the animals along their track. The division between the abysses and the slopes is rather a matter of temperature than of mere depth. But the temperature itself is somewhat dependent on the depth, the influence of the great warm currents rarely extending below seven or eight hundred fathoms and this depth corresponds roughly to a temperature of about forty degrees Fahrenheit. Below this it diminishes as the depth increases, at the rate of about one-tenth of a degree to one hundred fathoms until the freezing point is reached, though there is no reason to suppose that the abyssal water ever actually becomes congealed.

To this cold dark area of the Ocean bottom has been applied the name of the Benthal or Abyssal region.

To the region, chiefly on the continental slopes, between the Litoral and Abyssal regions, I gave some years ago the name of the Archibenthal Region.

These divisions have been recognized by various writers and have had several terms applied to them. Those I have mentioned seem to me as characteristic as any, and in some respects more convenient than any I have heard used.

Let us now consider the conditions under which life exists in the Abyssal and Archibenthal regions. It may be premised that the differences between them are largely of degree and not of kind and do not require that the two regions should be considered separately.

The chief characteristics reside in the composition of the sea water, including its contained gases; in the dynamic status of the deeps, especially in relation to temperature and pressure;

in the mechanical qualities of the materials of which the oceanic floor is composed; and, lastly, in the food supply.

As determined by physicists and chemists the water of the deep sea varies in the proportions of mineral salts, carbonic acid and air contained in it very much as does the surface water. In general at the surface the warmer water of the tropics has the more salt and the less nitrogen. When carried by currents to the Polar regions, and cooled, this tropical water sinks to the bottom carrying its excess of salt along with it. The Polar waters are less saline and contain more nitrogen. The proportion of atmospheric air in the water is found strictly related to the temperature, the pressure at great depths being regarded as having no bearing on the question. The amount of oxygen in the sea water diminishes gradually as we descend from the surface until about 350 fathoms is reached, when it ceases to change or at most increases slightly until the bottom is attained.

Carbonic acid, according to Tornœ, does not exist in a free state in sea water, but only in the form of carbonates or to a less degree of bicarbonates. Unless the decomposition of animal matter in some manner sets free the carbonic acid, this conclusion is one which cannot be adopted without question, especially when we consider the great difficulties which are encountered in any attempt to obtain, or when obtained to analyze, abyssal water. The effect of erosion on the shells dredged, from the deeps, even when they contain the living animal, is so strongly marked, the devices for protection against erosion are so recognizable in various species, that the biologist may well call the physicist to a halt, while the latter re-examines his data. It is certain that erosive agencies, of which the effects are indistinguishable from those known to be due to carbonic acid in other instances, are extremely active in the deeps.

In general it seems as if we might safely assume that the composition of abyssal sea water shows no very important differences from that of other sea water and that the animals existing in it are not exposed to any peculiar influences arising from this source alone.

This cannot be said of the physical conditions. Everyone knows how oppressive to the bather is the weight of the sea water at only a few feet below the surface, and how difficult it is to dive, still more to remain on the bottom, if only for a few seconds.

But it is difficult to convey any adequate idea of the pressure at such a depth as 2,000 fathoms, or about two miles below the surface.

Rope made impervious by tarring is said to have become reduced one-third in its diameter by a descent into these depths. Any hollow object not pervious or elastic, is at once crushed. There is no doubt that at some points on the ocean floor the pressure may amount to several tons to the square inch.

If we recall that the average pressure in steam boilers is probably much less than one hundred pounds to the square inch it may help toward an appreciation of the abyssal conditions.

The inevitable conclusion is, therefore, that all the animals living under these conditions must have their tissues so constituted as to permit the free permeation of the water through every part in order that the pressure may be equalized. How this is possible without putting an end to all organic functions is perhaps the greatest mystery of abyssal life. How can a large egg, like those of various deep-sea animals, pass through the stages of segmentation and development, with every molecule of its structure in actual contact with ordinary sea water and every solid particle subjected to a pressure of say a thousand pounds to the square inch?

Such questions are much easier to ask than to answer, in fact no attempt at an answer has, so far as I am aware, ever been offered to biologists.

The looseness of tissue necessary to such a permeation is conspicuous in abyssal animals, whose flabby and gelatinous appearance when they reach the surface is notorious. It is perhaps most noticeable in the fishes, which nevertheless are often armed with formidable teeth. But under the great pressures of the deeps it is quite conceivable that each of these loose and half dissolving muscles may be compressed and reduced to a condition resembling steel wire ; and that the organization thus sustained may be as lithe and sinewy in its native haunts as its shallow water relatives are in theirs.

It is well known how great an influence on the distribution of shallow water species is exerted by the temperature of the water in which they live. No doubt the differences of temperature affect the nervous system, the rate of muscular contraction, and the motions of the cilia by which in mollusks many of the functions of life are aided or wholly carried on.

But it is probable that the influence of temperature is far more effectively exerted upon the development of the ova, and hence upon the propagation of the species, than directly upon the parents. It is probable that most adult mollusks could endure a very wide range of temperature if the individuals were subjected to the changes by extremely slow degrees. But it has been shown that a difference of one or two degrees below a certain point on the thermometric scale, will destroy the embryos of *Ostrea* or prevent their development so that they perish. In this way the spread of the species may be effectually checked, though the adult shellfish may flourish without difficulty in the same region.

In the shallower parts of the Archibenthal Region, a few great currents, like the Gulf Stream, may reach, for a small part of their course, the ocean floor and sweep it clean of sediment and detritus, if not entirely of living beings. Such mechanical effect as is produced must be of a rather steady and uniform nature for considerable periods and in no respect resemble the crushing and grinding which take place on every exposed beach on which the sea rolls up. In fact, regarded as individuals, the mollusks in the path of the Gulf Stream and other great currents, have little or nothing to fear from the mechanical attrition which plays so large a part in the shallows. On the other hand wherever the force of the stream is not sufficient to sweep the bottom clean, the supplies of oxygen and food brought by it to the colonies along its path so far exceed the normal for quiet waters, that the animals thus favored flourish and multiply in a manner never seen in quiet deeps.

The influence of darkness upon the inhabitants of the Abyssal Region has often been expatiated upon. The absence of visual organs or their preternaturally excessive development beyond the normal of the groups to which the individuals belong is evidence enough that the deeps are markedly darker than the shallows. But this evidence proves too much for the claim that the deeps are mathematically dark. Whatever notions may be entertained or conclusions deduced by the physicist from the premises, the presence of large and remarkably developed eyes in many abyssal animals shows that light of some sort exists even on the oceanic floor. It is inconceivable that these organs should be developed without any light and if the experiments and reasoning of the physicist result in the apparent demonstration of absolute darkness in the depths, the facts of nature show that in his premises or his experiments there lurks some vitiating error. It is ridiculous to suppose that the phosphorescence of certain animals in the deep sea fauna is a factor of sufficient importance to bring about the development of enormous and exquisitely constructed eyes in a multitude of deep sea species. A greater or general phosphorescence, such as would amount to a general illumination, has never been claimed by any scientific biologist and, as a theory, requires a mass of proof which seems unlikely to be forthcoming.

In general then we find the physical conditions simpler than those of the shallows and yet much more energetic. The effect of temperature is marked in the distribution of life over cold and warmer areas of sea bottom. The relative importance of the effects of pressure, partial darkness and of the quietness of abyssal waters, our knowledge is yet too imperfect to allow us to precisely estimate. All doubtless have their effect ; some of the effects are more obvious than others, but it is by no means certain that the most obvious are necessarily the most important to the organisms concerned.

The mechanical character of the sea bottom is of greater importance than is generally realized. In a very small proportion of its extent the sea bottom is composed of bare or nearly bare rock. Away from the shores such a bottom is usually situated in the trough of some great current like the Gulf Stream, and then seems to be nearly bare of animal life. In other cases it may be found on the walls of sub-marine cliffs, which for obvious reasons can hardly be explored for marine life with our present appliances.

The rest of the bottom consists of solid matter in different stages of sub-division, from something which may be described as calcareous gravel to an impalpable mud which may or may not be dotted with concretions of manganese, iron or other mineral matter. The gravels are chiefly confined to the archibenthal region, the true deeps are generally carpeted with a viscid layer of the finest possible calcareous mud or clay. The latter formation is meagre in its fauna as clay is when it occurs in shallow water.

Certain forms of mollusk-life flourish in a soft bottom especially the *Nuculidæ* and their allies which are notably abundant in the depths as well as in the muddy shallows of the Litoral Region. Others require some solid substance upon which to perch, a stone, a bit of wood, a spine from some dead Echinoderm, something they must have for themselves and for their eggs which shall raise them above the muddy floor. In regions where such objects are rare or absent on the sea bottom such mollusks are equally rare or wanting. Most ingenious are the shifts made in many cases, as when we find *Lepetella* safely housed in the tubes of dead Annelids or Hydroids, and *Choristes* taking refuge in the empty ovicapsules of rays or sharks. Small hermit crabs take to the tooth-shells (*Dentalium*) or to the tubular Pteropods (*Cuvierina*); or *Amalthea* roosts on an *Echinus* spine and builds for itself a platform as it grows, recalling the arboreal houses of some Oriental savages.

In the Archibenthal Region there is a more or less constant drift of debris from the adjacent shallows which gradually forms banks of considerable magnitude.

The action of erosion and solution for some reason seems less potent here than in either the shallower or the deeper parts of the sea. In the shallower parts the excess of motion, in the deeps the excess of the eroding agent, may account for this. The fact is known to me from the study of many specimens from both regions and is beyond question.

A feature in forming certain of these banks, to which attention has hitherto not been directed, is worthy of mention. This is the habit of certain fishes, which exist in vast numbers, of frequenting certain areas where they eject the broken shells of mollusks, corals, barnacles and other creatures which they have cracked, swallowed and cleansed of their soft tissues by digestion. We have learned from Darwin of the marvelous work of the earthworm in Britain. The ejectamenta of a single fish of moderate size in one day would far exceed the accumulations of many earthworms for much longer time. Now, in examining critically large quantities of material dredged from the bottom I have found that from certain areas almost entirely composed of these ejectamenta. In the interstices some small creatures hide but the tooth marks of the fish were upon nearly every fragment. As for a pint of fragments of a given species, this bottom-stuff would rarely contain half a dozen specimens which had been taken alive by the dredge (most frequently the species did not occur at all living in the material so dredged), it was obviously impossible that the shells could have been captured and afterward voided on the same spot. It seemed more likely from all the facts that these fishes after feeding to repletion repair in large schools to certain areas to enjoy the pleasures of digestion. There would be nothing improbable in the fish of a limited region preferring some special locality for this purpose ; and the result might be the accumulation of a veritable bank, of which nearly the whole had at some time or other passed through the intestine of a fish. At all events, whatever explanation be offered of them, it is certain that such accumulations do occur at certain localities, as shown by the dredgings of the Fish Commission off the eastern coast of the United States.

The last condition remaining to be considered is that of the food supply. It has long since been pointed out that marine vegetation ceases to exist within a limit of six hundred feet below the surface. Whatever light exists in the depths, it is not of a nature to meet the needs of vegetation. Whether any other factor joins with the absence of light to discourage algal growth is yet unknown but not intrinsically improbable. The mollusks which belong to groups known as phytophagous in shallow water, in the deeps appear to live chiefly on foraminifera which they swallow in immense quantities. The results of this diet are evident in the greatly increased caliber of the intestine relatively to the size of the animal, in the diminution of the masticatory organs, teeth and jaws, and in the prolongation of the termination of the intestine as a free tube to a length which will carry the effete matters out of the nuchal commissure, and thus free from their injurious effects the branchial organs, which are usually seated in this space. The quantity of nutriment in the protoplasm of foraminifera is so small that a much larger mass in proportion of these organisms must be swallowed and their remains consequently ejected afterward, than if the food consisted of the tissues of algæ.

But the great mass of abyssal mollusks are members of those groups which in shallow waters are normally carnivorous, and to a great extent prey upon one another. In the deeps however this reciprocal destruction is unnecessary.

Those who have become familiar with surface collection on the sea alone can realize the immense quantity of organisms which exist in the water on or near the surface. These are frequently numerous enough to reduce the water to the consistency of soup, for miles in extent and to a considerable depth. Millions of these creatures are constantly sinking from the region where they naturally belong, either from injury or exhaustion, and thus raining slowly but constantly upon the bottom. This fact is not new and is admitted to be unquestionable by all biologists. Hence in many regions of the sea bottom the resident fauna have, as it were, only to lie still and hold their mouths open.

One of the facts which attracted my attention when I first begun to study deep sea mollusks was the singularly small number which showed signs of having been drilled or attacked by other mollusks. Apart from those showing the marks of fish teeth or the dental machinery of echinoderms, it is extremely rare to find drilled bivalves or univalves such as make up the great mass of the jetsam on every sandy beach. Such cases occur, but the occurrence is always exceptional and the holes which are most often found in abyssal shells are those which are due either to the friction of some hermit crab or to the erosive properties of the secretions of certain annelids which fix their irregular tubes upon the outer surface of the shell. These injuries cannot easily be confounded with the circular drill holes of carnivorous gastropods.

Having handled more deep sea mollusks than any other naturalist now living, and spent, probably, more time over material procured by the dredge from shallow water, than anyone else of my acquaintance, I do not feel that I am presumptious in affirming the remarkable difference which obtains in this respect between the dead material from the Litoral and from the extra-Litoral regions, respectively.

This brings me to a conclusion which I have elsewhere published with less detail. The animals belonging to the mollusca which are found in the Archibenthal and Abyssal regions, especially the latter, do not live in a perpetual state of conflict with one another. A certain amount of contention and destruction doubtless goes on, but on the whole the struggle for existence is against the peculiarities of the environment and not between the individual mollusks of the area concerned. It is an industrial community, feeding, propagating and dying in the persons of its members and not a scene of carnage where the strong preys upon his molluscan brother who may chance to be weaker. Depredations on this community are doubtless committed by deep sea fishes and echini, perhaps by other organisms, but the inroads are not so important as to seriously modify the course of evolution and influence specific characteristics.

Hence the course of evolution and modification, though still complex, is certainly much less so than in the shallower parts of the ocean. For this reason we may hope to penetrate more deeply into its mysteries with deep sea animals than with those less fortunately situated. In this opportunity, to me, lies the chief importance of research into the biology of deep sea mollusks. Nowhere else may we hope to find the action and reaction of the contending forces less obscure, and modification in most cases has not extended so far that we cannot compare the deep sea forms with their shallow-water analogues and draw valuable conclusions.

While we are not yet in a position to formulate conclusions covering all the details of abyssal mollusk-life in certain instances results suggest themselves.

Deep sea mollusks of course did not originate in the depths. They are the descendents of those venturesome or unfortunate individuals who, by circumstances carried beyond their depth, managed to adapt themselves to their new surroundings, survive and propagate. Many species must have been eliminated to begin with. Others more plastic, or more numerous in individuals, survived the shock and have gradually spread over great areas of the oceanic floor. In accordance with these not unreasonable assumptions we should expect to find among the newer comers at least some characters which were assumed under the stress of the struggle for existence in the shallows, and which, through specific inertia, have not become wholly obsolete in the new environment. We should also expect to find a certain proportion of Archibenthal species in any given area, identical with or closely related to the analogous Litoral region forms of the adjacent shores.

In the Abyssal region alone should we expect to find that any considerable proportion of the fauna has lost all its litoral characteristics, assumed characters in keeping with its environment and become disseminated over the ocean bottom throughout a large part of its extent. These expectations in the main are fairly satisfied by the facts as far as the latter are positively ascertained.

With the lesser need of protection from enemies and competitors would necessarily be related a less rigorous elimination of characters which in struggle and competition might prove sources of weakness. The limits of uninjurious variation would be relaxed at the same time and to the same extent. We find as we should expect that the deep sea mollusks are more variable in their ornamentation and other superficial characters than those from shallow water. In some species the balance of characters is fairly well maintained ; in others variation runs riot, and it is impossible to say what amount of it should constitute a basis for specific subdivisions among individuals.

In general deep sea shells present pale or delicately tinted color patterns, are white, or owe their color to the tinting of the epidermis. This may be due directly to the absence of light. Sunlight, when present, seems to have a stimulating effect in developing colors as is shown by the greater brightness of tropical litoral shells whatever their colors. It operates indirectly by promoting the development of color in algæ which are fed upon by phytophagous mollusks, and affect the coloration of the latter directly through the assimilation of the coloring matter of the food, mechanically.

Indirectly, through the influence of protective mimicry, the coloration of shells which frequent beds of seaweed or rocks covered with stony algæ, is often modified in harmony with the environment even when the species is not phytophagous.

In the deeps these influences are wanting and the development of color is necessarily the result either of uneradicated hereditary tendency, or of some physical features of the environment which operate mechanically and are not yet understood.

The colors chiefly effected by deep sea mollusks are pink or reddish straw color, salmon color, and various shades of brown. These are found in the shell and are more or less permanent. The epidermis of deep sea shells is usually pale yellowish, but frequently is of a delicate apple green, such as is seen in many fresh water species; and sometimes of a beautiful rich dark chestnut brown, a color also not rare among land and fresh water species. The most common pattern when any exists is that formed by squarish dark spots which occasionally become fused into bands. Among the Archibenthal species found in depths from 100 to 300 fathoms this pattern of brown squarish spots arranged in spiral series is notable in such forms as *Scaphella junonia*, *Aurinia dubia*, *Halia priamus*, *Conus mazei*, etc. Instances of the green epidermis are afforded by the various species of *Nuculidæ*, *Turcicula* and *Buccinidæ*.

The thick and solid layers of aragonite, of which many shallow water species are chiefly built up, are represented in deep water forms by much thinner layers, while the nacreous layers are, if not more solid in abyssal shells, at least more brilliant and conspicuous, perhaps because less masked by aragonitic deposits. A very large proportion of the deep water shells are pearly and derive their beauty from the brilliance of their nacre.

In the matter of sculpture the mechanical effect of the pressure operates against the development of weight and thickness in benthal shells since the whole must be permeable. It is probable too that the soft and sticky character of the abyssal ooze would put the possessor of an unusually heavy shell at a considerable disadvantage in getting about on the bottom. Any impermeable shelly structure on the ocean floor would have to be strong enough to sustain without crushing a weight hardly less than that borne by the rail under the driving wheel of an ordinary locomotive. It is sufficiently obvious from a mere statement of the case, that none of them can be impermeable.

The heavy knobs or arborescent varices of shallow water Murices are represented in their deep water congeners by extremely thin and delicate spines and slender processes. These are probably all reminiscences of shallow water ancestors, as it is difficult to imagine any cause which in the abysses would lead to a development of such defenses *de novo*.

The sculpture most usual on deep water shells is of a kind which serves to strengthen the structure, much like the ridges which give rigidity to corrugated iron work or the curves used by architects in wrought iron beams. Spiral or longitudinal hollow riblets, a transverse lattice work of elevated laminæ such as are developed for similar reasons on the frail larval shells of many gastropods, a recurvature of the margin of the aperture in forms which in the Litoral region never develop such recurvature ;—these are instances in point.

Beside these there are small props and buttresses developed which serve the same purpose of strengthening the frail structure at its points of least resistance. Such is the garland of little knobs so commonly found in front of the suture in abyssal shells of many and diverse groups.

It is not intended to suggest that the methods above indicated have not been developed also in shallow water forms and for similar reasons. The distinction which I would point out is that in Litoral species, as a rule, these devices are subsidiary to the much simpler course of strengthening the shell by adding to its thickness. In the abyssal forms, for reasons already explained, this mode is not practicable and consequently we have the one without the other.

The operculum is generally horny in abyssal mollusks, frequently disproportionately small, compared with that of congeneric litoral species, and in a remarkably large number of cases is absent altogether.

The genus most abundantly represented of all is *Mangilia*, which is entirely without an operculum, and affords a conspicuous example of the obsolescence of protective devices, originally acquired in shallow water, resulting from long residence in the deeps.

In the Unio and Melania of fresh water streams and the pondsnails of our lakes and ponds, the waters of which from the decay of vegetable matter are overcharged with carbonic acid, we find a dense thin greenish epidermis developed as a protection against erosion. In the deep sea where every portion of the shell must be permeated by the surrounding element to equalize the external pressure, and where carbonic acid exercises its usual malign influence on the limy parts of all organisms, we find a strikingly similar protective epidermis developed in most unexpected places. Thus it comes about that in the *Trochi*, *Pleurotomidæ* and other characteristic abyssal animals we find those puzzling and remarkable counterparts of land and fresh water shells which have astonished every student of the mollusca who has seen them. These deep water species imitate in almost all superficial characters of the shell the biologically wholly different pondsnails and landsnails.

Similar exigencies of the environment have provoked similar mechanical responses in the shelly parts, a result wholly in harmony with the modern postulates in biological science.

As might be expected of descendents with modification there are greater similarities between the larval shells of benthal species and those of their shallow water relations, than between the parts of the shell, which are of later growth in the same forms. There is one notable difference however. In the deep water forms the nucleus is frequently larger than in their shallow water analogues. It would seem as if the conditions of the depths were such, that, of a small number of large larvæ, more are likely to survive than of a larger number of smaller ones; or at least that that form of larval growth is more useful to the species.

These details will serve to show the multiplicity of facts to be accounted for and the opportunity for advancing science by a study of abyssal conditions and their effects upon the animals subjected to them. Without claiming any unique importance for the theories advanced in the foregoing remarks it may still be said that the subject is one of the very greatest interest. Perhaps experiments upon shallow water forms, artificially subjected to pressure may at some future time enable us to penetrate more deeply into the mysteries of life in the abysses.

The attempt to prepare a summary of bathymetrical data for the deep sea fauna of any region yet investigated, is most unsatisfactory in its outcome from the paucity of data. Most of the species of any collection are represented by the shells alone, which may have been—as millions are daily—disgorged by fishes, and never have lived at the depth from which they were dredged. We are yet ignorant as to whether the abyssal and archibenthal faunæ shade gradually into one another, as seems most probable ; or whether there is any line of depth, coincident with a temperature limit, which really fixes a boundary for the abyssal fauna.

Then, again, the difficulty and time involved in a cast of over one thousand fathoms are so much greater than if it were made in half that depth, that it is impossible to say what proportion of the disparity in population between the Archibenthal and Abyssal areas, which dredgings seem to indicate, is due to the fact that the latter have been far less efficiently explored. The only thing of which I feel confident is that it is yet too early for extensive numerical comparisons or deductions based wholly on statistics. I shall therefore content myself here with a very modest table, which is intended to illustrate the peculiarities of the collection made during the past ten years by the U. S. Steamer *Blake* and recently reported on by me.

It is probable that it is a fair example of abyssal mollusk faunas, but this cannot be claimed with certainty.

The first table shows the general numerical results for the *Blake* collection, assorted among the great systematic groups and the three bathymetric zones or areas. The second table shows the proportion to the whole population of the abyssal region borne by those genera which exceed a single species. The result here shown is that less than thirty-seven per cent. of the genera comprise more than sixty-eight per cent. of the species ; and out of these, three families, *Pleurotomidæ*, *Ledidæ*, *Dentaliidæ* furnish nearly twenty-eight per cent. of the species of the abyssal fauna collected by the *Blake*.

TABLE I.

General Numerical Results.

Groups	No. of Genera	No. of Species	Species in the Litoral Area	Species in the Archib. Area	Species in the Abyssal Area	Species common to Two Areas	Species common to All Areas	Abyssal Fauna Families.	Abyssal Fauna Genera
Brachiopods .	7	13	8	12	3	8	2	2	3
Pelecypods .	52	170	98	114	31	64	10	15	19
Scaphopods .	2	35	17	28	12	17	5	1	2
Gastropods .	119	491	280	222	83	161	32	29	41
Totals . .	180	709	403	376	129	250	49	47	65

TABLE II.

Genera represented by more than one Species in the Abyssal Area.

Genera.	No. of Species.	Genera.	No. of Species.
Mangilia	17	Fluxina	2
Margarita	5	Liotia	2
Pleurotoma	4	Leptothyra	2
Drillia	3	Cocculina	2
Marginella	3		
Scala	3	Leda	5
Calliostoma	3	Limopsis	3
Triforis	3	Pecten	3
Actæon	3	Abra	2
Utriculus	2	Myonera	2
Fusus	2		
Columbella	2	Dentalium	8
Benthonella	2	Cadulus	4

Total, 24 Genera and 87 Species.

For the naturalist of to-day the most interesting feature of abyssal life is not that it furnishes him with singular and archaic forms, useful in his study of extinct genera ; nor the beauty and rarity of the creatures living under such unusual conditions. The most important characteristic of abyssal life is, that it, and it alone, exhibits a fauna in which reciprocal strug-gle is nearly eliminated from the factors inducing variation and modification. There is no mimicry or sexual selection, where all is dark. Indeed, if it could be shown that the deeps are absolutely dark, the acknowledged development there, by some animals, of large and supersensitive eyes, might be a proof of the Lamarkian doctrine of development consequent on effort, as opposed to the views of Darwin, that it is solely the result of selection conscious or unconscious and the survival of the fittest.

In the struggle for life of the abyssal animal, he is pitted against the physical character of his environment, and not against his neighbor or the rest of the fauna. Hence we should have, and really do have, the process of evolution less obscured by complications in the abysses than is possible elsewhere. From a study of these animals in the light of their environment, much may be hoped toward the elucidation of great questions in Biology, and naturalists everywhere should strive to promote deep sea dredging as essential to the progress of Science.